Computational Prediction of Aerodynamic Drag for a Simplified Truck Geometry

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SAE International Truck and Bus Meeting and Exposition

November 14, 1999

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Outline

- Sandia Ground Transportation System (GTS) project history (including TAMU experiment)
- Approaches to flow simulations
- Issues with computational boundary conditions
- RANS simulations for TAMU experiment
  - Different yaw angles (0^o & 10^o)
- Ongoing Efforts
- Concluding Remarks

Acknowledgement

Sandia Ground Transportation System (GTS) Project (1993-1996)

Walter T. Gutierrez

Basil Hassan

Robert H. Croll

Jose E. Suazo

Mary A. McWherter-Payne

Walter P. Wolfe

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Ground Transportation System (GTS) Baseline Geometry

Project had two parts:

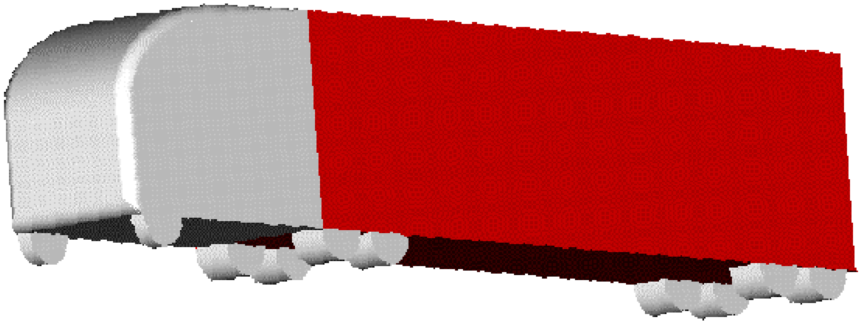
- Experimental (TAMU)
- Computational

Cab-Over Tractor-Trailer

For simplicity

- Mirrors,
- Wheel wells,
- Tractor-trailer gap,

not simulated.



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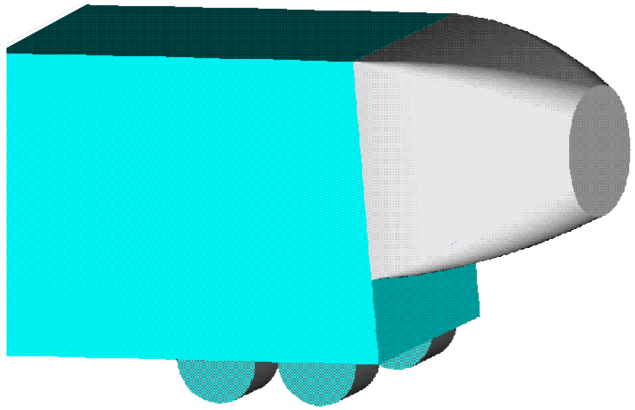
Add-on Geometries: Ogives and Slants

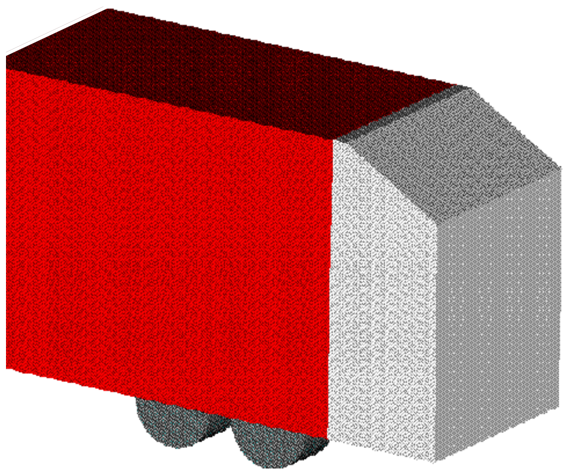


Ogival Boattails

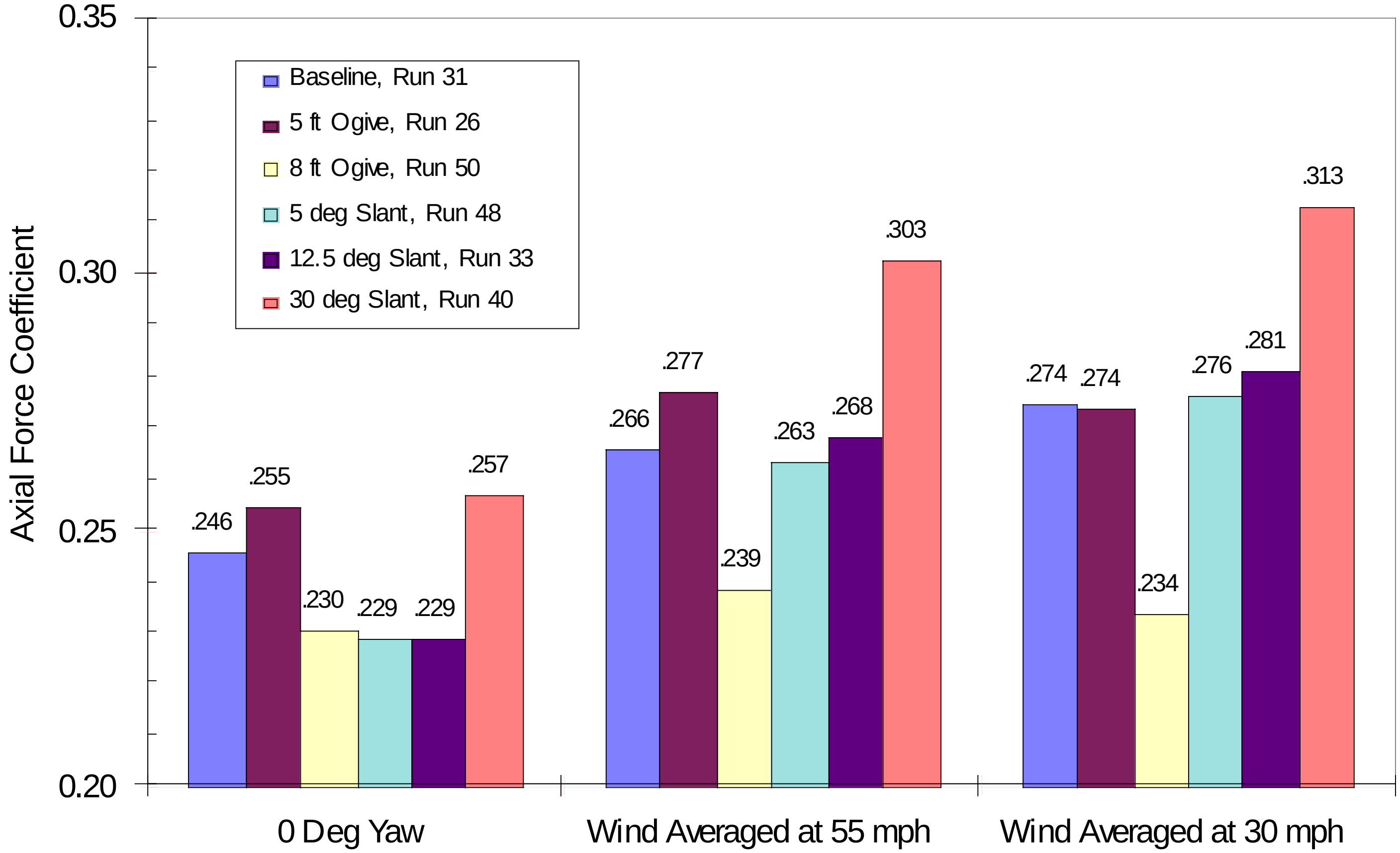
- **1.5 m (5 ft) and 2.4 m (8 ft) long**
- **Tangent at top of trailer and sides**
- **Blend from square to circle**
- **Primarily boundary layer separation**

Slants

- **5, 12.5, and 30 fastbacks**
- **Scaled from work by Ahmed, et al.**
- **Primarily boundary layer separation and vortex interaction**



Axial Force "Drag" Coefficient
Texas A&M Experiment



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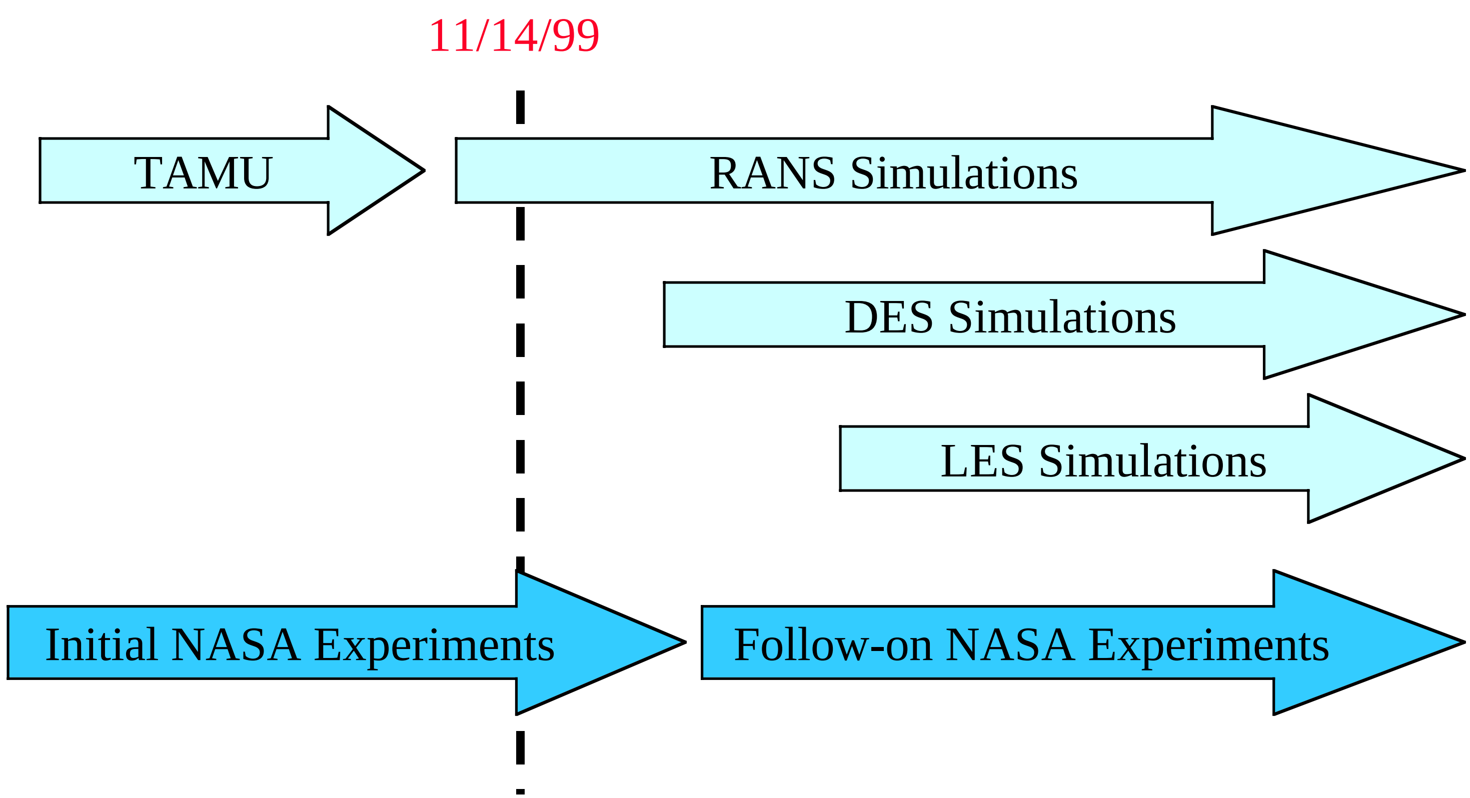
Sandia Computational Approach

Simulation of Flow Field Around Heavy Vehicles

- Reynolds Averaged Navier-Stokes (RANS)
- Detached Eddy simulations (DES)
- Large Eddy simulations (LES)

Sandia Computational Approach, Cont.



SACCARA Code Capabilities

Sandia Advanced Code for Compressible Aerothermodynamics Research and Analysis

- **Multi-block, structured grids for 2-D, Axisymmetric, and 3-D flows**
- **Solution of the Full Navier-Stokes equations for compressible Flows**
- **Finite volume spatial discretization (steady and unsteady)**
- **MP implementation on a variety of distrubuted parallel architectures (IBM, Intel, etc.)**
- **Implicit time advancement schemes**
- **Subsonic $\rightarrow$ Hypersonic flows**
- **Zero-, one-, and two-equation turbulence models**
- **Ideal, equilibrium, and thermo-chemical nonequilibrium finite-rate gas chemistry**
- **Rotating coordinate system**

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SACCARA Code Capabilities, Cont.

SACCARA is a Modern Navier-Stokes Code

The code can be executed on range of computing platforms, such as, high-end PC, single workstation, parallel workstation clusters, and MP machines.

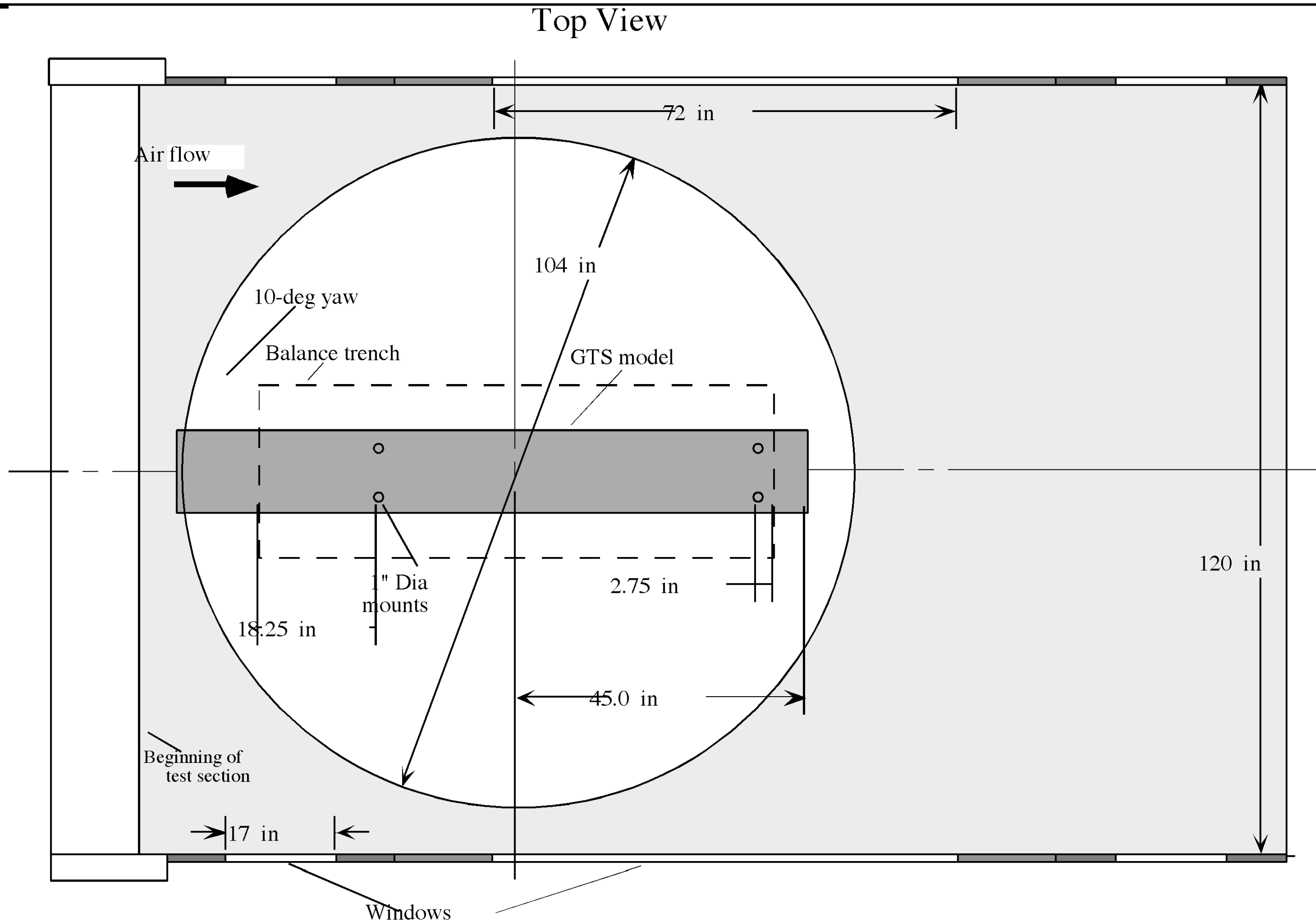
The code has comprehensive plan for Verification & Validation.

Computational Boundary Conditions

Modeling Wind Tunnel Experiment

- Inflow
  - Boundary layer profile
  - Uniformity of the incoming flow
  - Description of turbulent fluctuations (intensities)
- Outflow
- Far Field boundary
- Modeling tunnel walls (blockage)

GTS Model Installation at NASA 7'x10'



GTS Model: Ames 7x10 Installation

Scale: 1" = 1.75'

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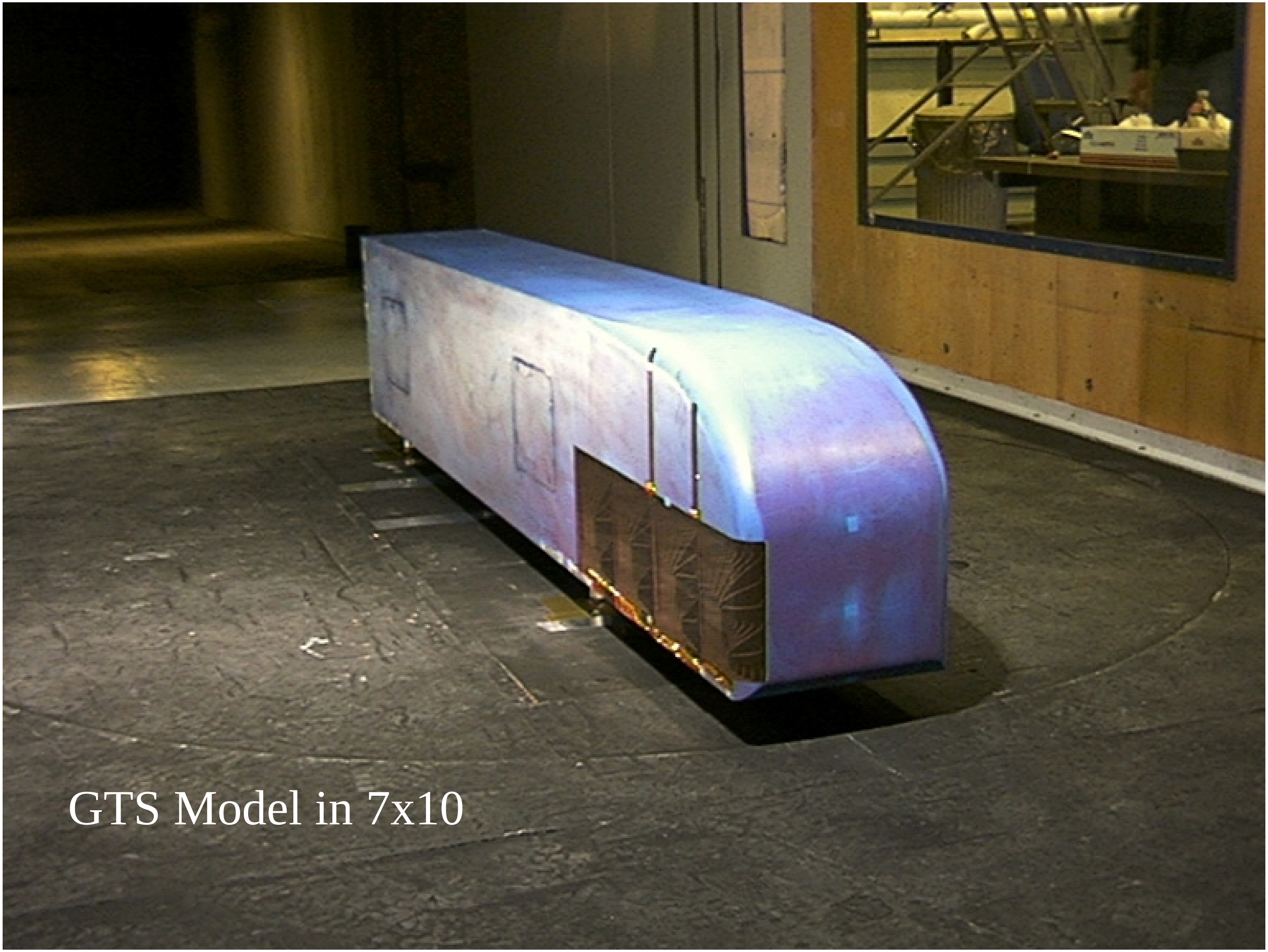

GTS Model in 7x10

GTS Flow Simulation, Texas A&M Test

Test Condition for run 31, no wheels:

$Re = 1.6 \times 10^6$

Yaw angle = 0° and 10°

Free stream velocity = 78 (m/s)

Free stream Mach number = 0.23

Density = 1.17 (kg/m^3)

Static Pressure = 99,470.6 (Pa)

Kinematic viscosity = 1.555×10^{-5} (m^2/s)

Reference: Robert H. Croll, Walter T. Gutierrez, Basil Hassan, Jose E. Suazo and Anthony J. Riggins, "Experimental Investigation of the Ground Transportation Systems (GTS) Project for Heavy Vehicle Drag Reduction," SAE Paper 960907, 1996.

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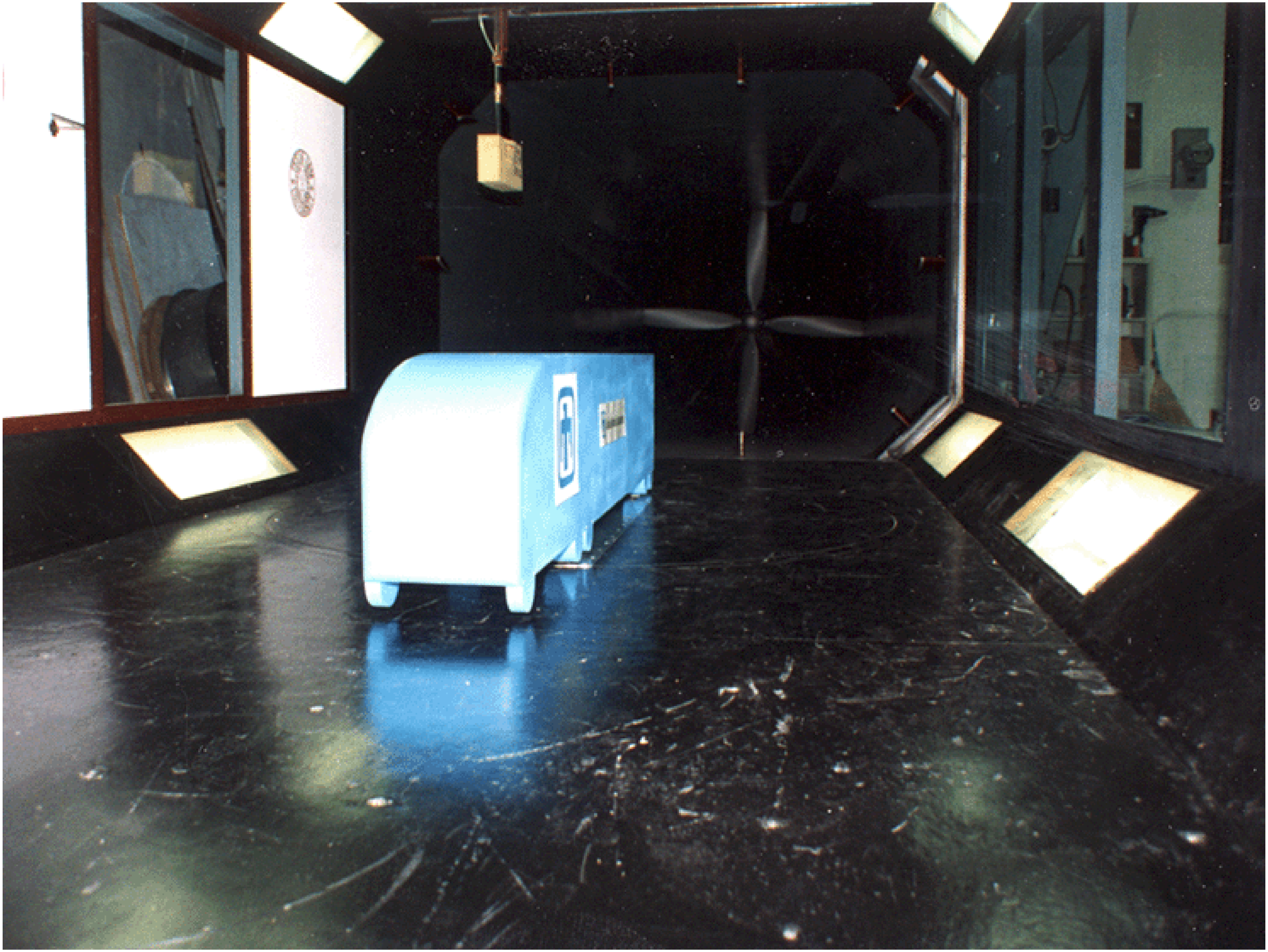
Matrix for Grid Convergence Study

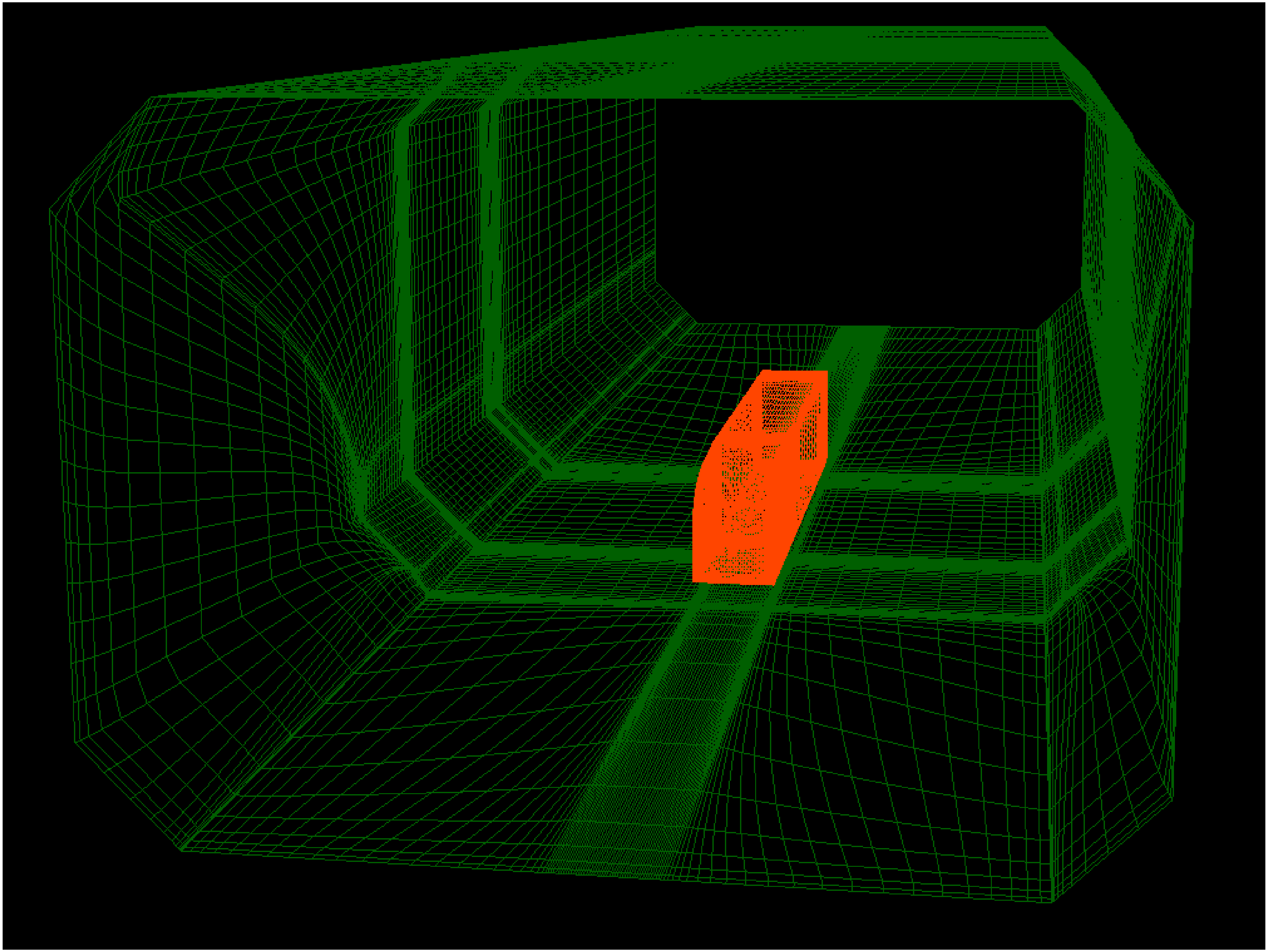
Yaw Angle	Grid Size		
	Coarse	Medium	Fine
0	X	X	In Progress
10	X	X	In Progress

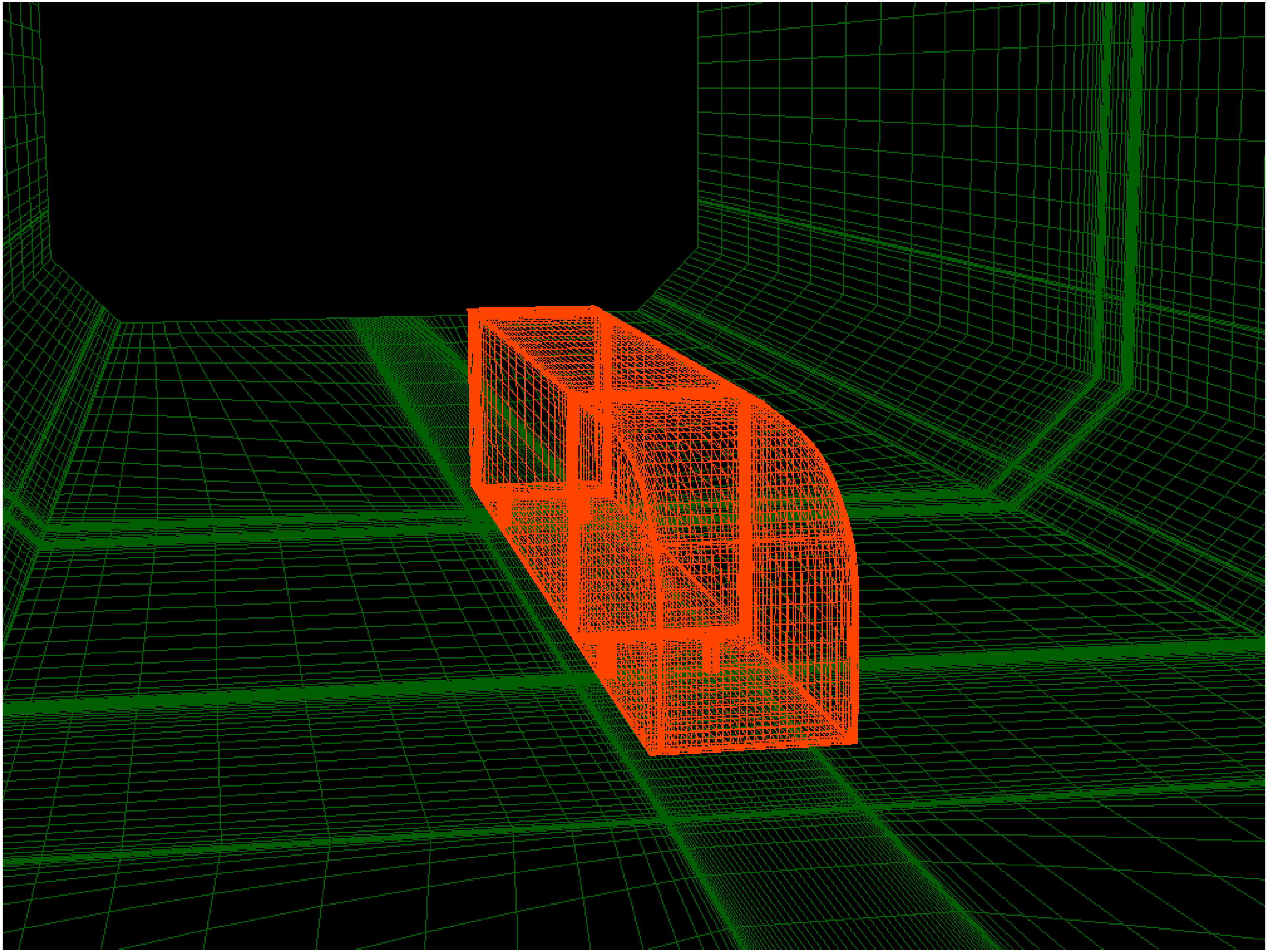
Coarse Mesh: 0.5 million nodes, 107 processors

Medium Mesh: 4 million nodes, 246 processors

Fine Mesh 32 million nodes, 1400 processors

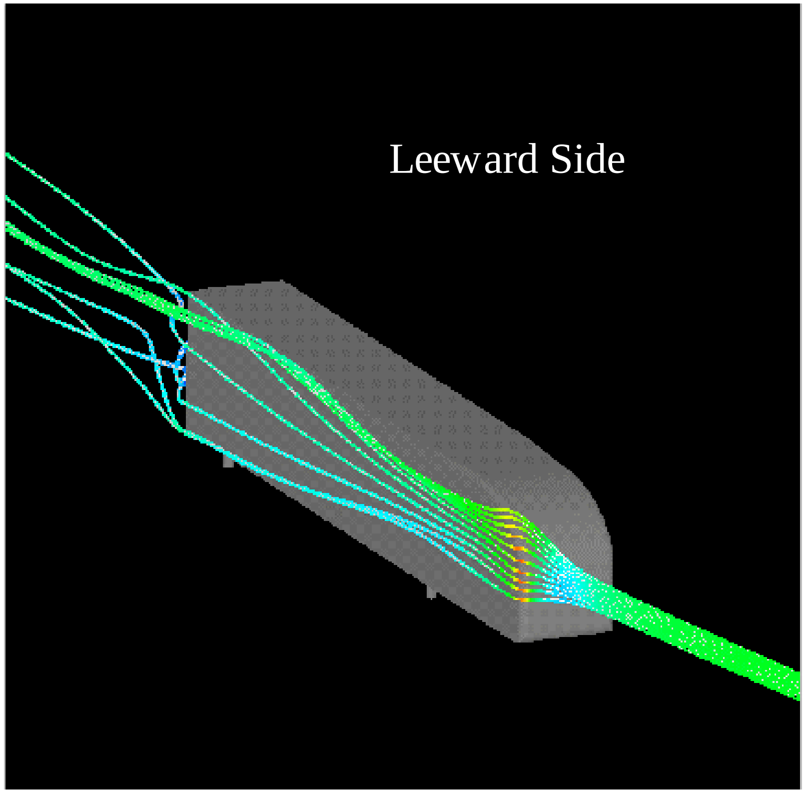


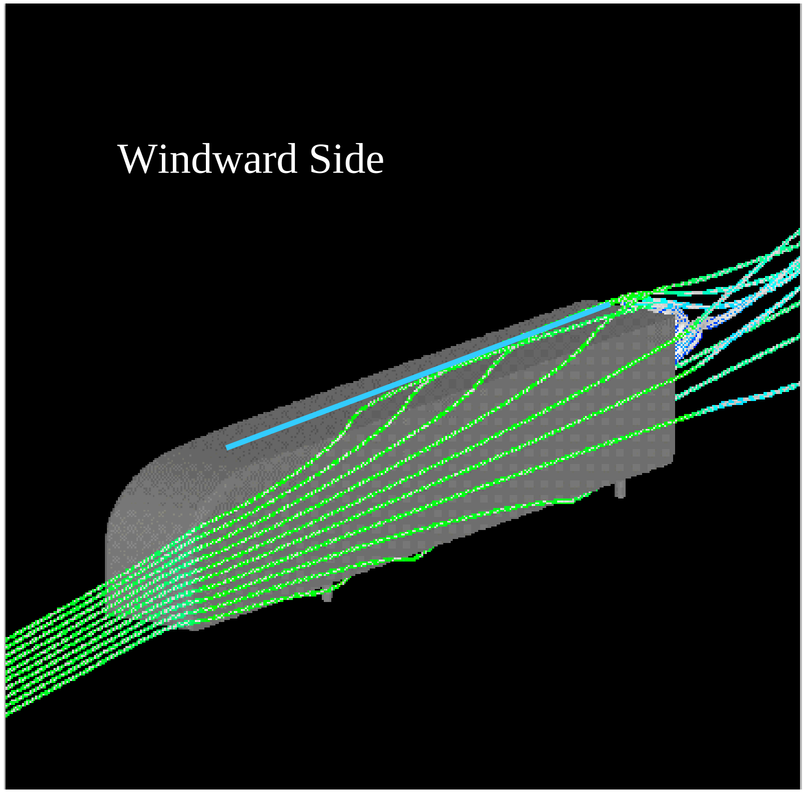




GTS Flow Simulation

10° yaw, Medium mesh, Particle traces are colored by velocity magnitude

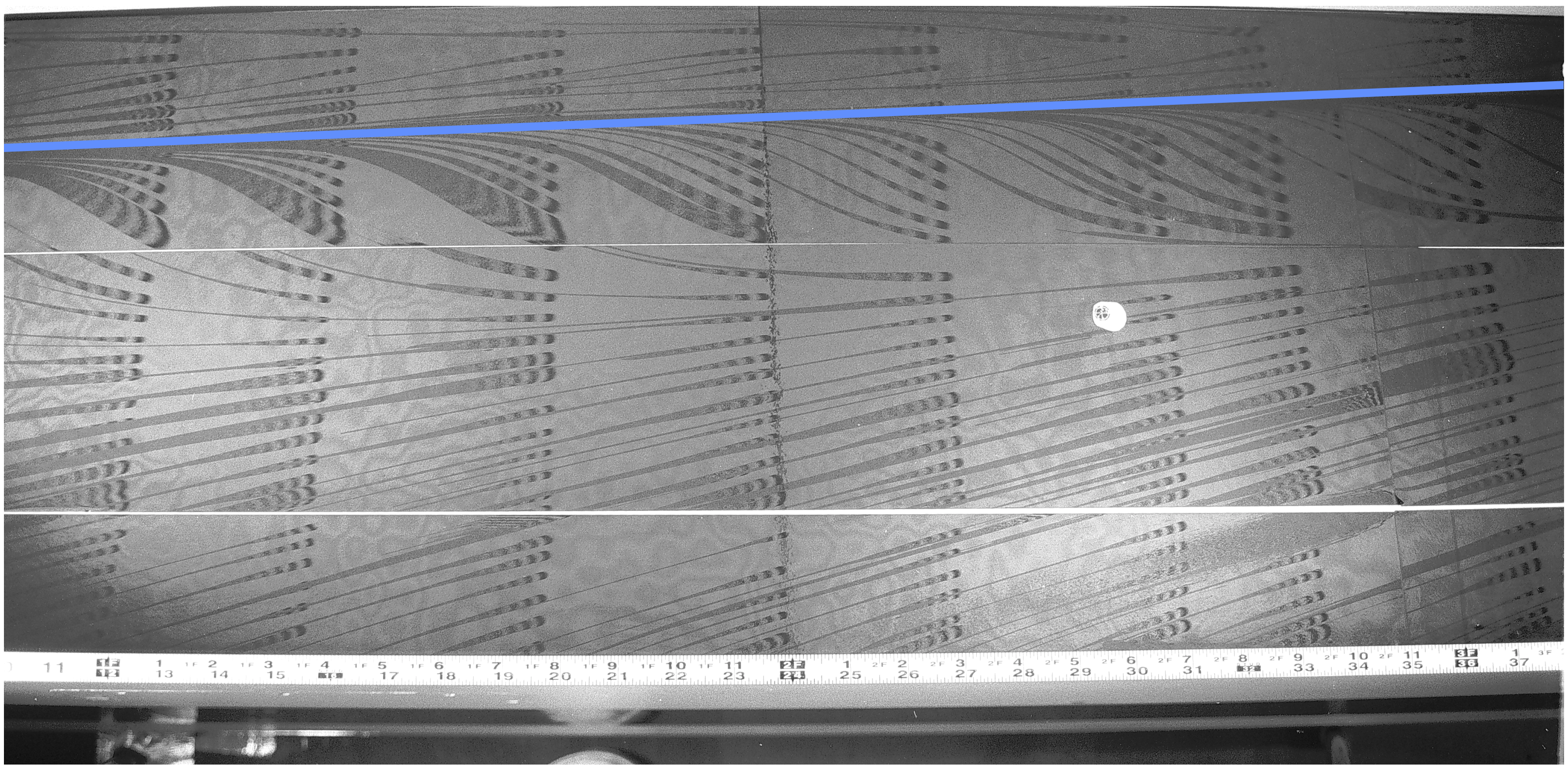




Oil Film Image

Top view of trailer at 10° yaw

V



Skin friction is proportional to fringe spacing

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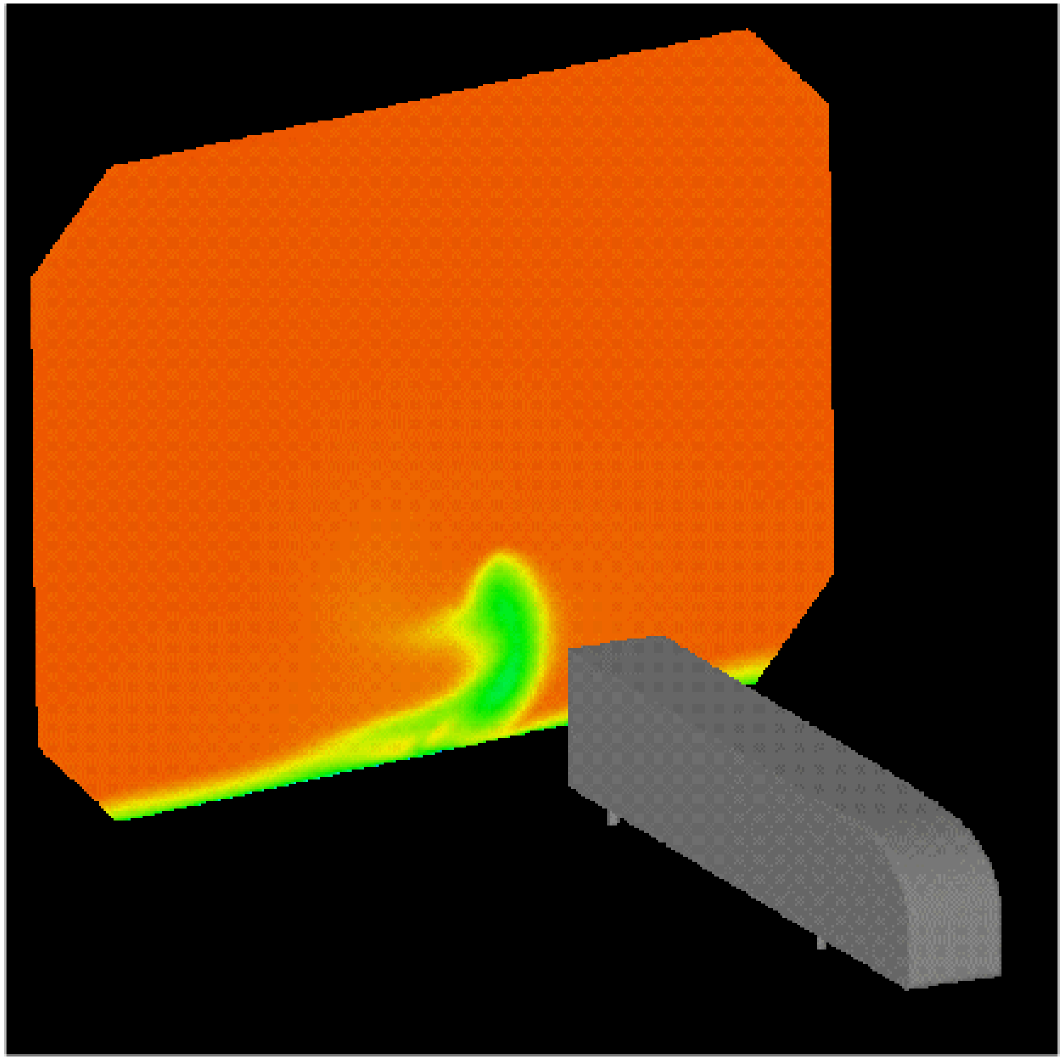
GTS Flow Simulation

10° yaw
x-plane cut
Mach contours



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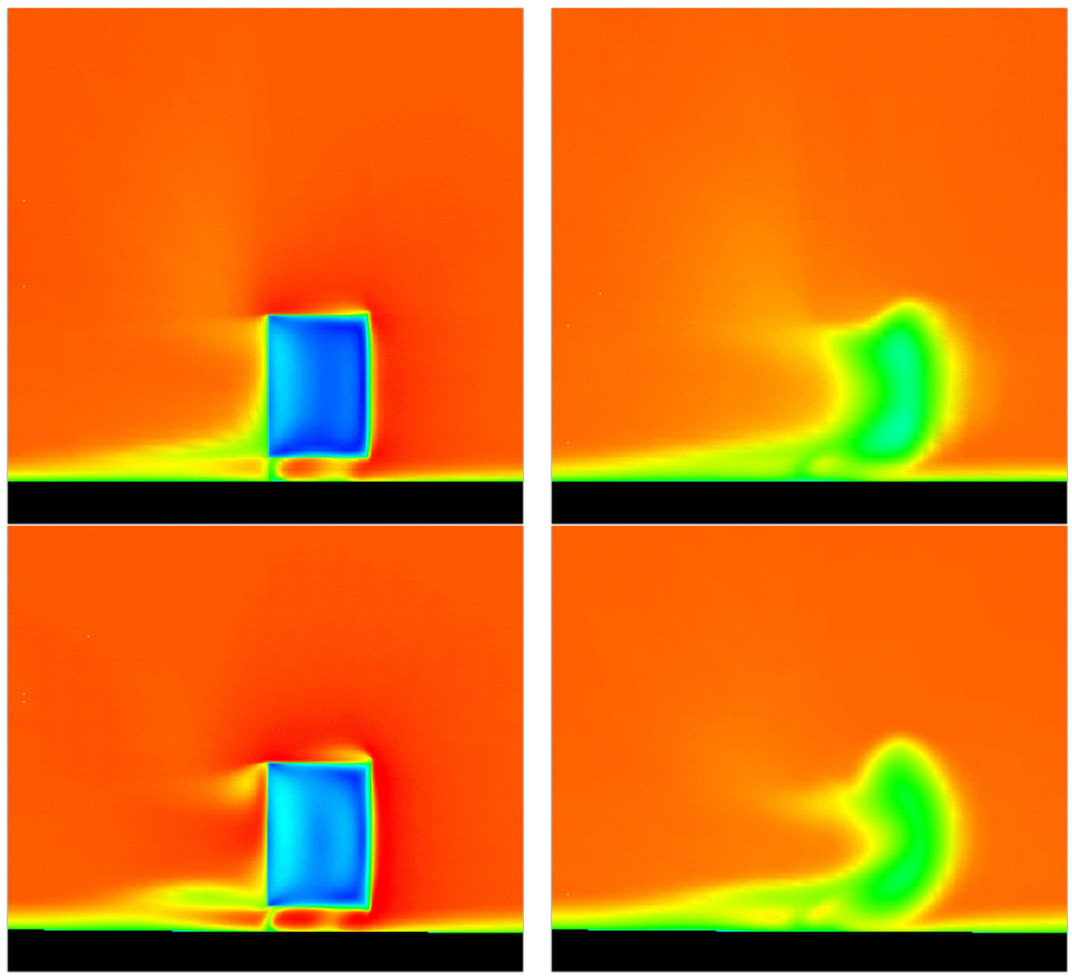
GTS Flow Simulation

10° yaw
x-plane cut
Mach contours

x = 2.5 m | x = 3.25 m

Coarse

Medium



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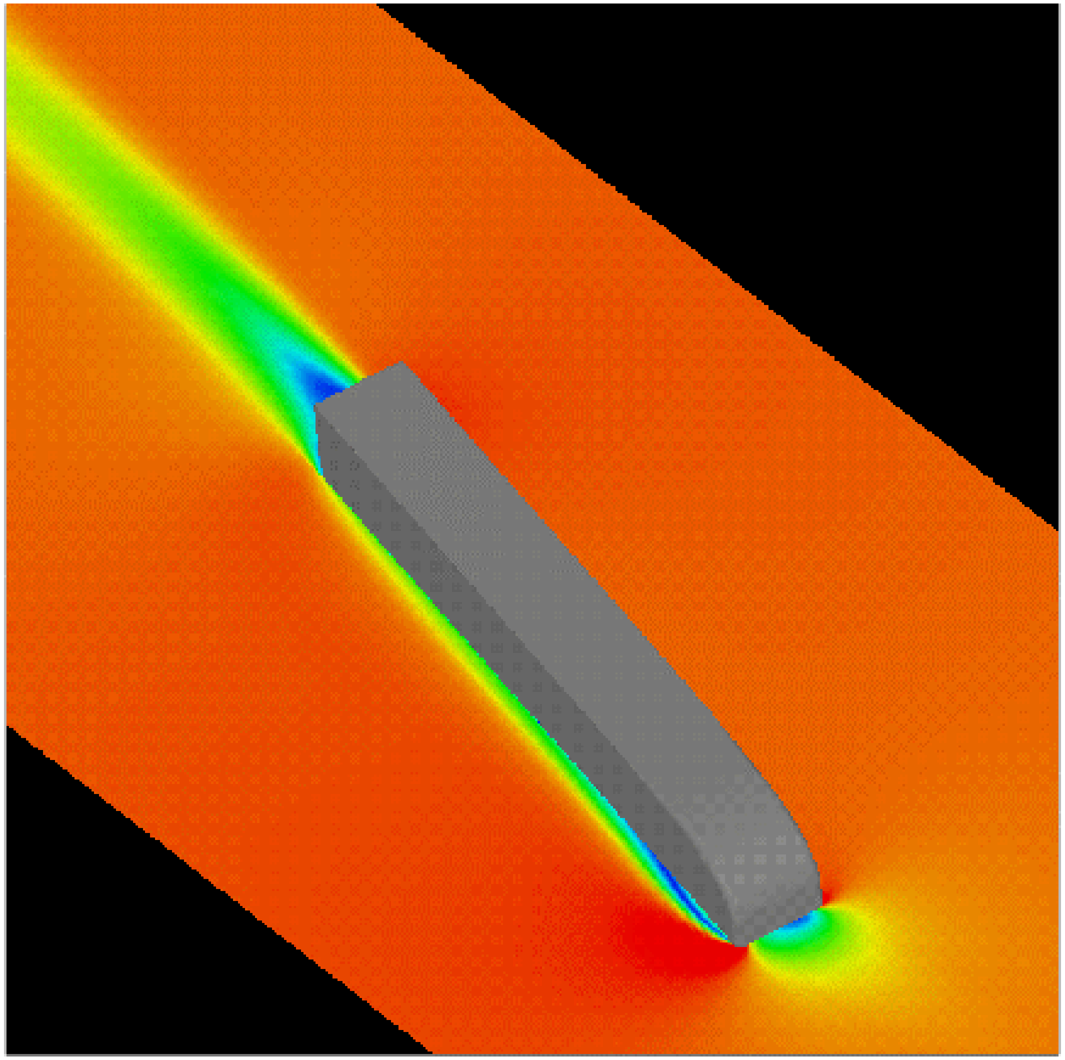
GTS Flow Simulation

10° yaw
y-plane cut
Mach contours



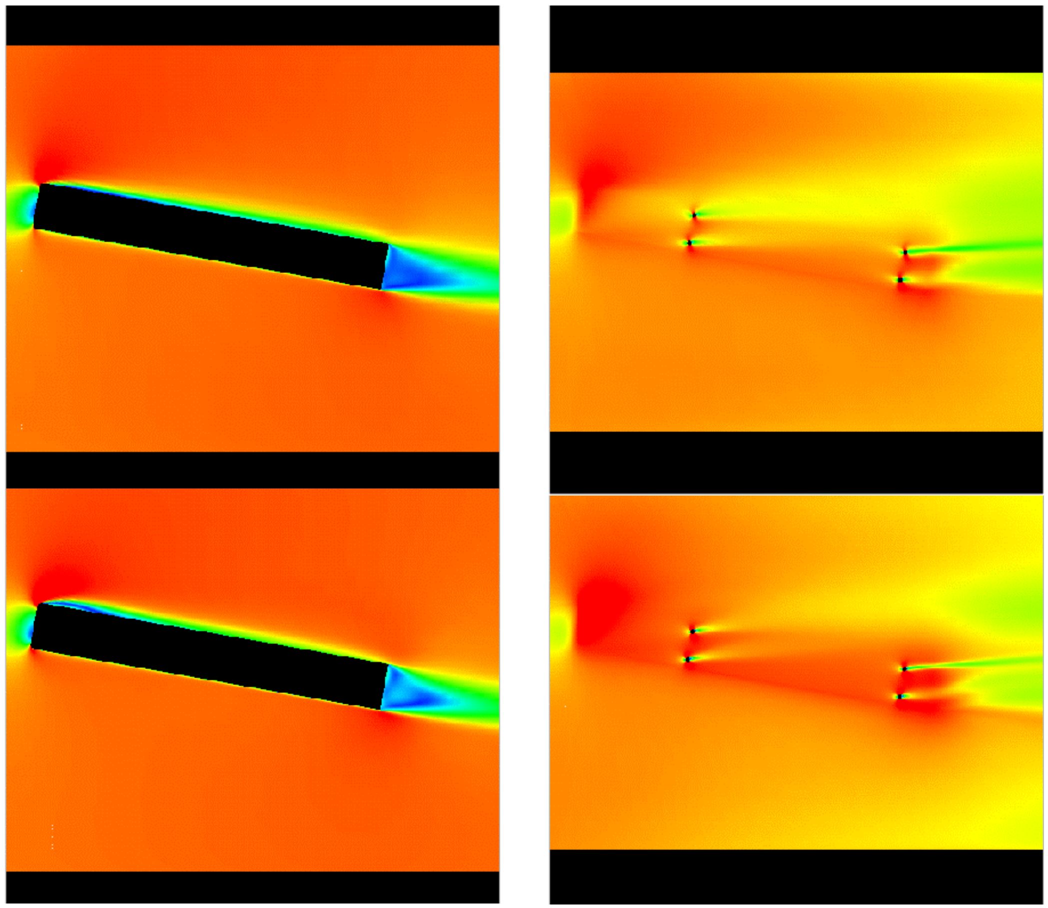
GTS Flow Simulation

10° yaw
y-plane cut
Mach contours

y = 0.122 m | y = -0.035 m

Coarse

Medium



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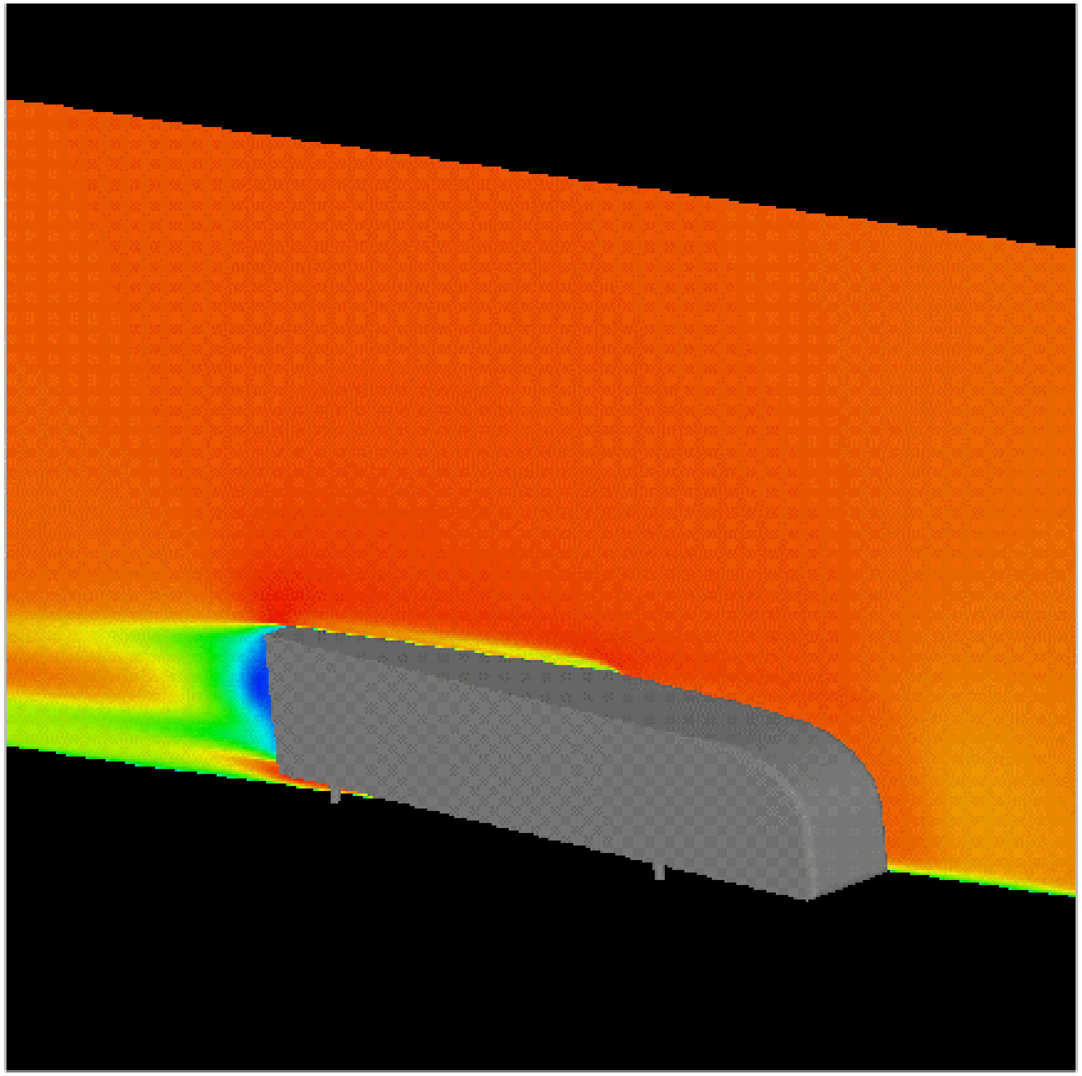
GTS Flow Simulation

10° yaw
z-plane cut
Mach contours



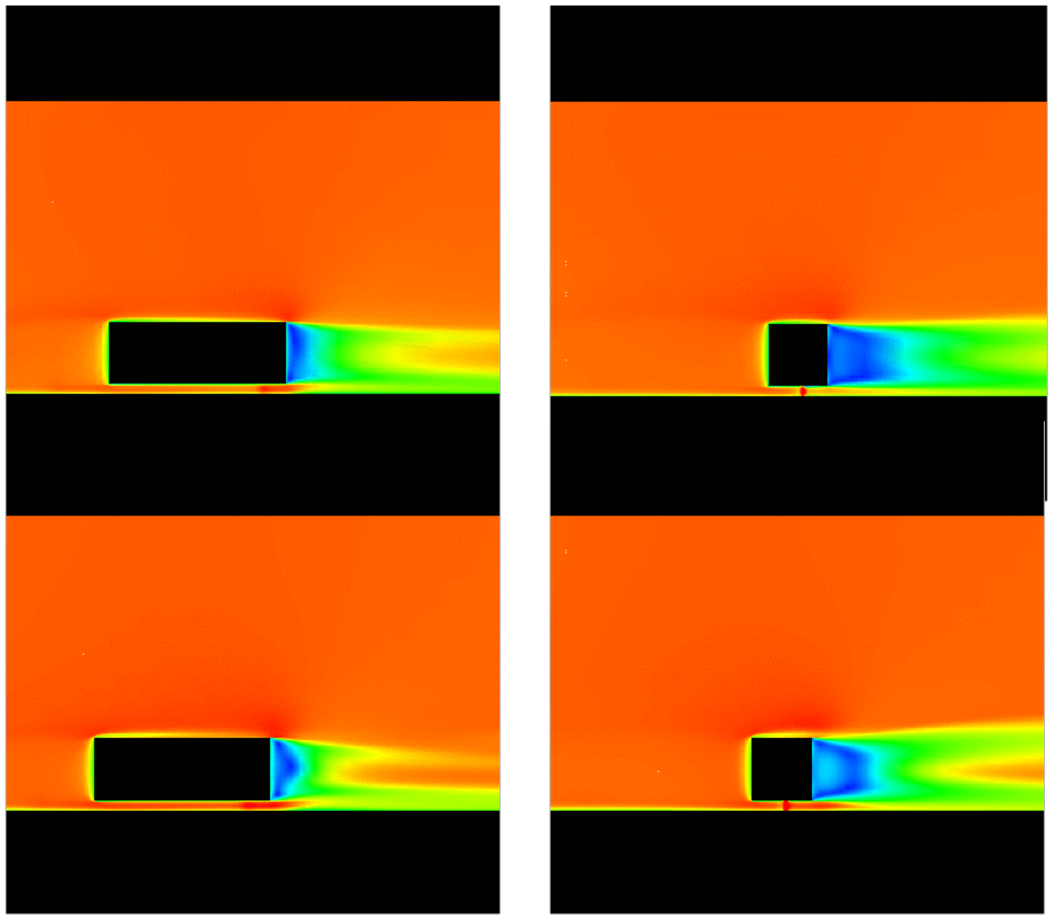
GTS Flow Simulation

10° yaw
z-plane cut
Mach contours

z = 0.07 m | z = 0.215 m

Coarse

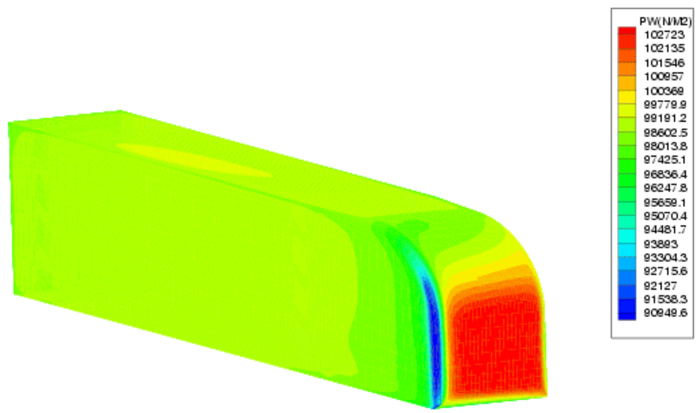
Medium

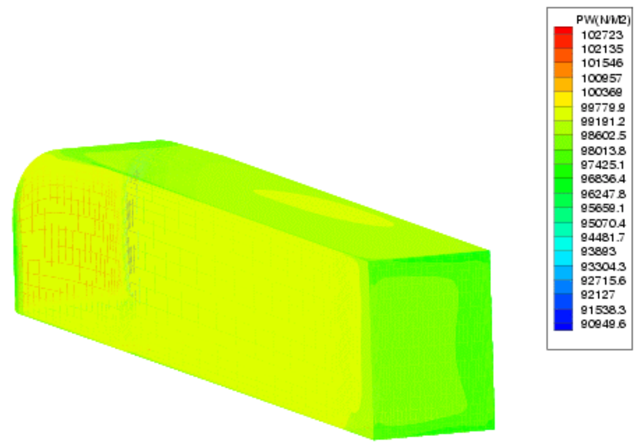


Pressure Distribution on the Surface

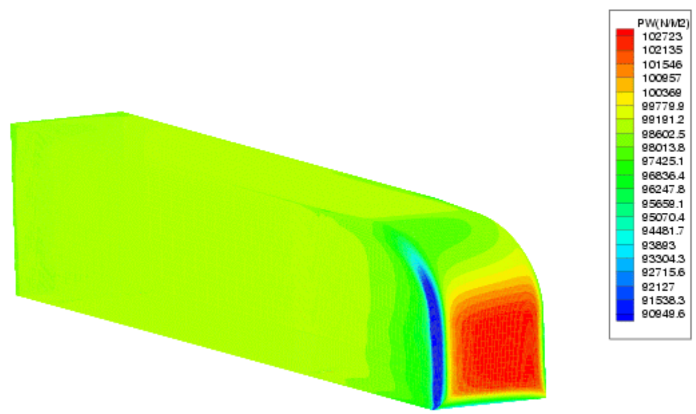
10° yaw

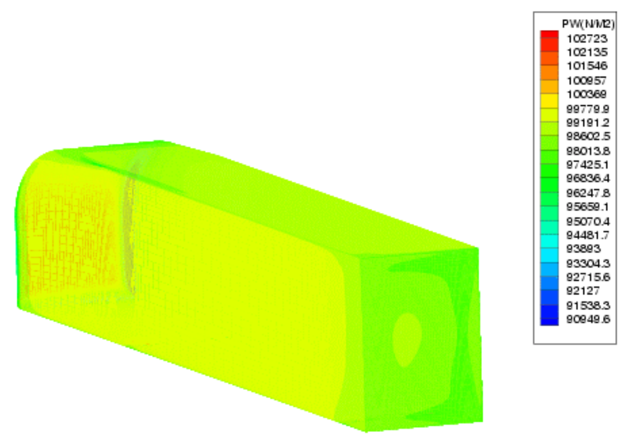
Coarse





Medium





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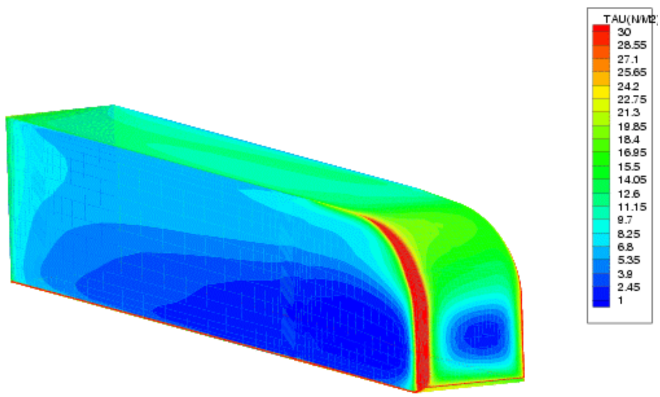
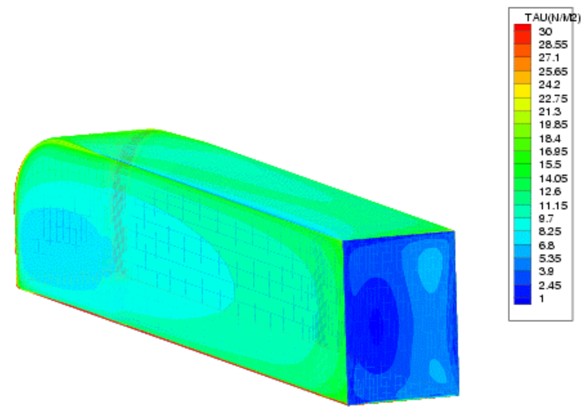
Shear Stress Distribution on the Surface

10° yaw

Coarse





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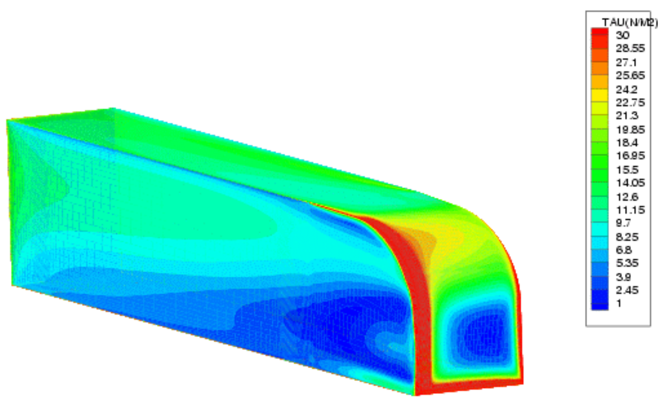
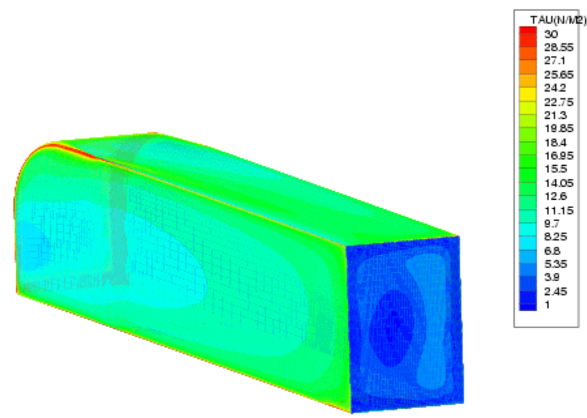
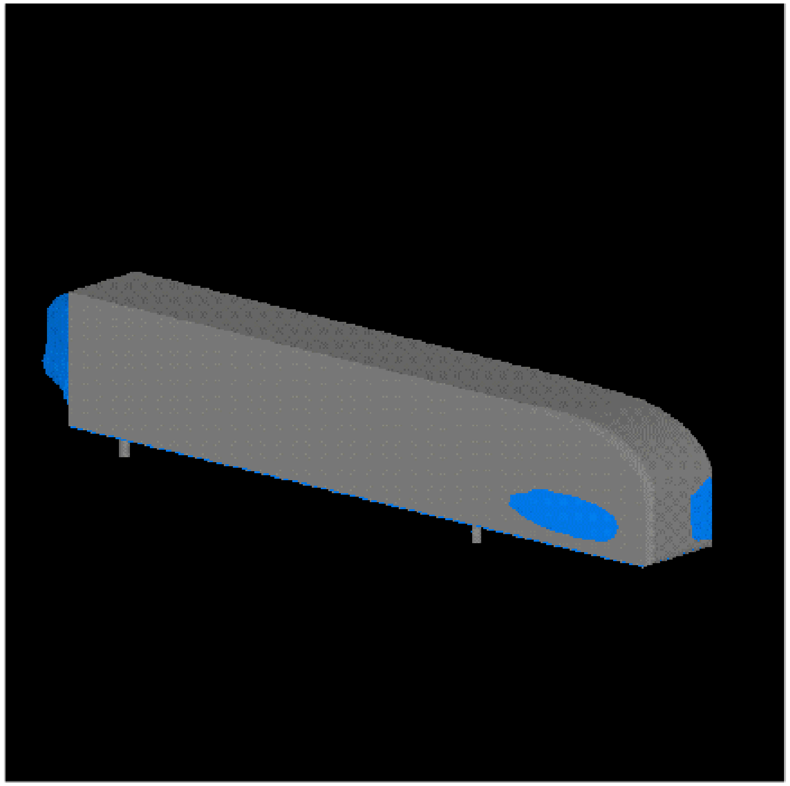




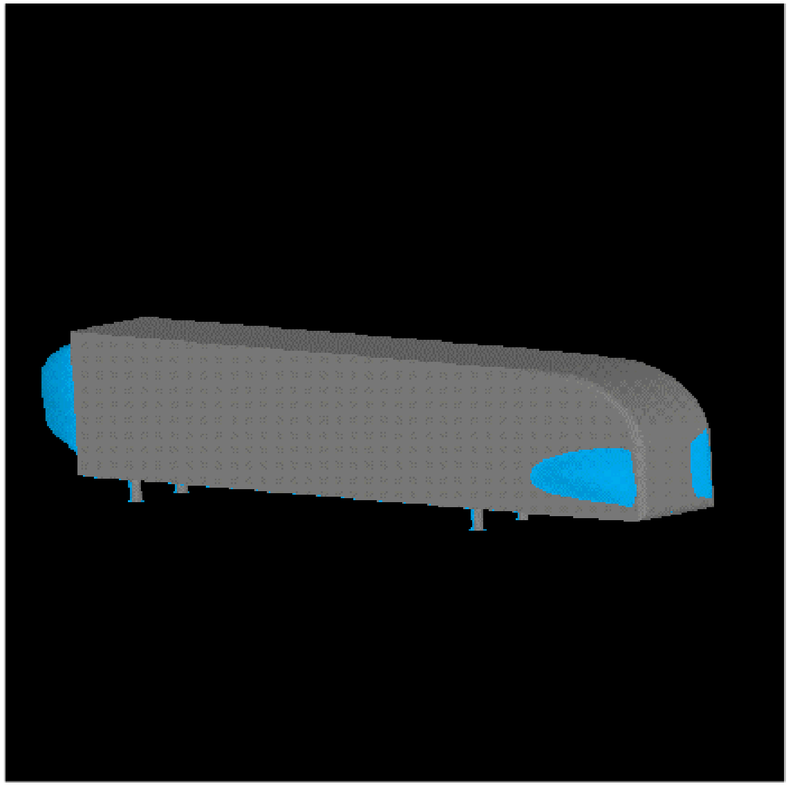
GTS Flow Simulation

10° yaw, IsoSurface u = -0.001 (m/s)

Coarse



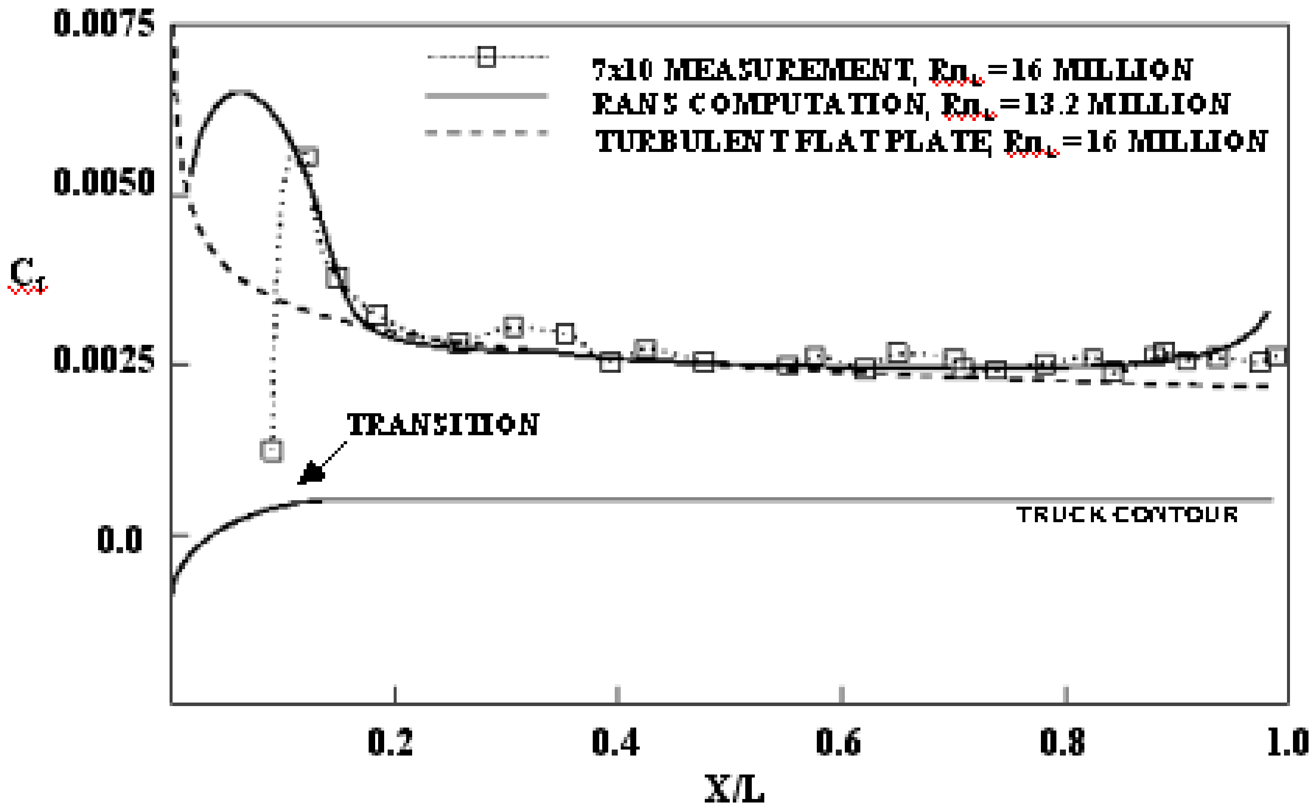
Medium



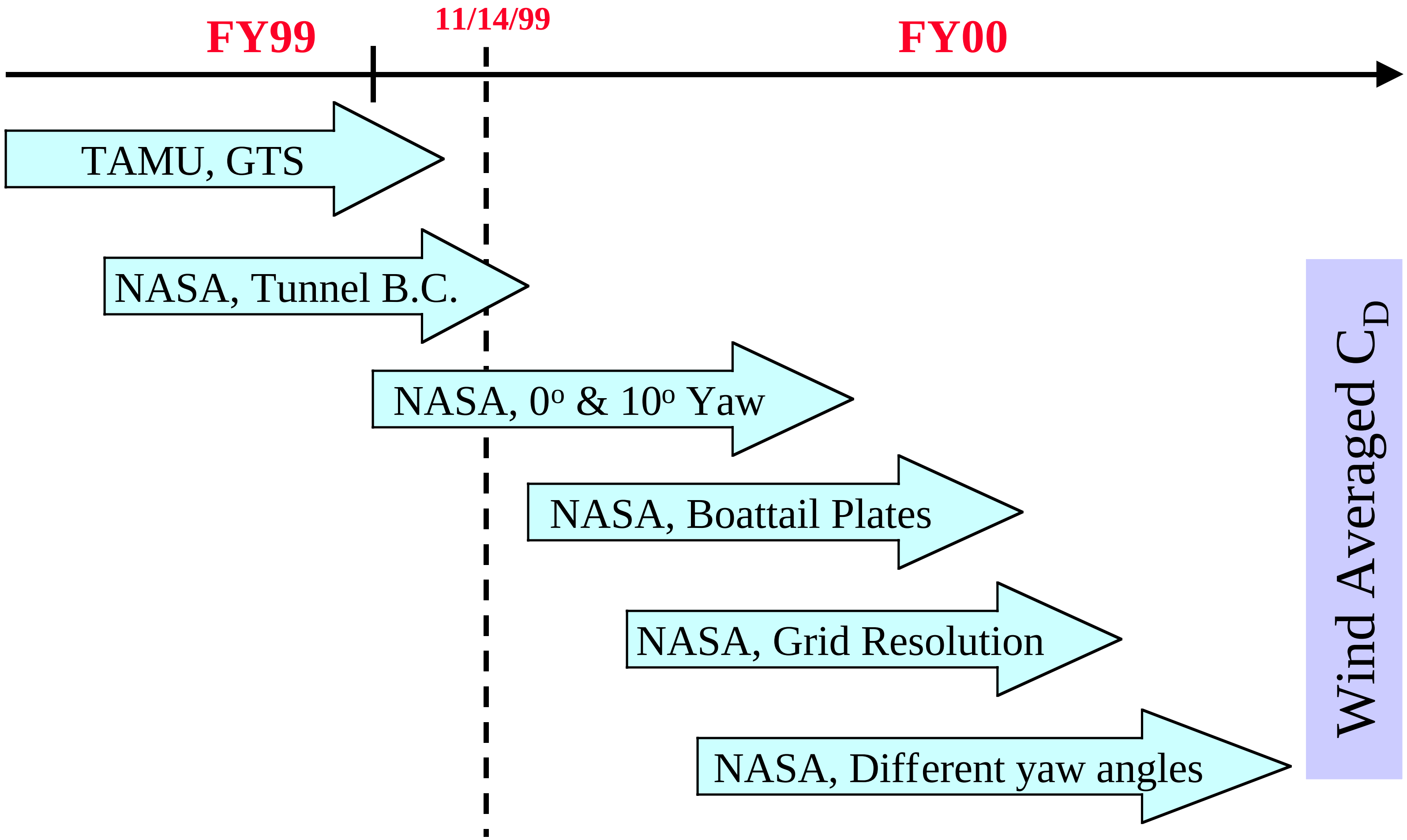
Skin Friction Comparison
NASA Experiment

Greg Zilliac, Dave Driver, NASA ARC

0° yaw, top surface, center line



Ongoing Sandia Simulations



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Concluding Remarks

- Demonstrate application of modern, state-of-the-art CFD technology to predict flow field around heavy vehicles.
- Starting with simplified shapes (such as GTS) for validation and then increase complexity
- Total vehicle aerodynamics (e.g., absolute drag)
- Relative effects from design changes (e.g., boattail plates, gaps, mirrors, etc.)

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